Appendix 1

Ozone Transport Assessment Group Modeling

Introduction

The Ozone Transport Assessment Group (OTAG) was a 37-state cooperative designed to assess regional ozone transport issues, and to develop recommendations for cost-effective measures to reduce regional ozone transport. OTAG assigned its Regional and Urban Scale Modeling (RUSM) workgroup the task of modeling different emission control strategies to determine each strategy's ozone reducing effectiveness. The workgroup accomplished this task by using the most recent version of the Urban Airshed Model (UAM-V) to model ozone concentrations for four episodes in 1988, 1991, 1993, and 1995.

OTAG completed four rounds of modeling using UAM-V. Different emission reduction strategies were employed and evaluated during the four rounds of modeling. OTAG concluded that regional NOx emission reductions were the most effective method of reducing modeled ozone concentrations inside the 37 state OTAG domain. OTAG demonstrated that domain-wide NOx emission controls reduce both surface and aloft ozone concentrations in Pennsylvania. Emissions from NOx affected units make up the majority of elevated point source emissions. OTAG sensitivity run 3a reduced these elevated NOx emissions by 60%. Ozone concentrations were reduced by 12-20 ppb in Pennsylvania. Sensitivity run 5g reduced elevated point source emissions by 80% and low level NOx emissions by 60%. Surface ozone concentrations were reduced by 12-20 ppb over a broader area of Pennsylvania. Aloft concentrations were reduced by 20-36 ppb over Pennsylvania. Aloft ozone concentrations are important because daytime vertical mixing transports ozone to the surface.

Actual ozone reductions from reduced NOx emissions could be higher since UAM-V underestimated ozone transport (as suggested by the modeling workgroup). All of OTAG's NOx domain-wide reduction strategies would substantially benefit Pennsylvania's nonattainment areas.

EPA modeled the 1988 episode as part of OTAG's emission control evaluation process. Its Policy Run included emission controls mandated by the Clean Air Act (CAA) in all current non-attainment areas, plus additional controls developed by the Ozone Transport Commission (OTC) for all states included in the Ozone Transport Region (OTR). The Policy Run's simulated ozone concentrations were in excess of 130 ppb in portions of Southeast and Southwest Pennsylvania Other parts of the Northeast modeled ozone concentrations greater than 160 ppb. This result suggested that even with all current and proposed emission controls, Pennsylvania and other Northeast states will not reach attainment with the current one-hour ozone standard. OTAG has shown that additional NOx controls throughout the OTAG domain are necessary to reduce regional ozone concentrations. Without these reductions, Pennsylvania will not be able to achieve and maintain the National Air Quality Standard for Ozone.

Subregional runs completed by OTAG showed upwind regions affect ozone concentrations in Pennsylvania. The Northeast Modeling and Analysis Center (NEMAC)

completed regional runs with no man-made emissions for the 1995 episode. Results from these zero emission runs were used to develop zones of influence for different cities in the Northeast. Pittsburgh and Philadelphia's zone of influence include the states of Virginia, West Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Tennessee, Arkansas, Missouri, Kentucky, Ohio, Indiana, Illinois, Michigan, Minnisota, Wisconsin and Iowa.

Results from NEMAC's subregional runs show that emission reductions outside of the OTR will benefit Pennsylvania's nonnattainment areas since much of the OTAG domain lies within Pittsburgh and Philadelphia's zone of influence.

Discussion of OTAG Modeling Results

The Ozone Transport Assessment Group (OTAG) was formed in May 1995 to address regional ozone transport. In an attempt to quantify the effects of regional transport, OTAG conducted several rounds of regional modeling for the 37 OTAG states. The OTAG modeling domain included areas from Texas to North Dakota and from Florida to Maine. Several rounds of modeling were completed as part of this project; the most extensive effort to date. Modeling results are available on the Internet at http://www.iceis.mcnc.org/OTAGDC/index.html.

A complete listing of the modeling group's conclusions is available in the Regional and Urban Scale Modeling (RUSM) Workgroup's final report. The following is a short list of some of the modeling group's consensus conclusions:

- The modeling was designed to provide an assessment of regional-scale concentrations and should not be used to address local regulatory issues, such as individual urban area attainment demonstrations.
- The limited number of episodes modeled may not represent all possible transport patterns or all possible nonattainment conditions.
- Models are tools for helping decision makers understand air-quality problems and evaluate potential control strategies. Models are most reliable for directional and relative assessments.
- Base-case modeling showed reasonably good agreement between simulated and observed surface ozone concentrations, with no large positive or negative biases. **Aloft, however, the model underestimated observed ozone concentrations, which suggests that the model may be underestimating transport.**
- **NOx emissions reductions are more effective than VOC emissions reductions in lowering ozone concentrations on a regional scale;** NOx reductions decrease ozone domain wide, while VOC reductions decrease ozone only in urban areas.
- **Elevated and low-level NOx emissions reductions are both effective in lowering ozone concentrations on a regional scale.**
- **More NOx emissions reduction results in more ozone benefit.**
- Regional NOx emissions reductions due to Clean Air Act mandatory controls, as well as possible OTAG controls, will reduce ozone and ozone precursors on a regional scale but may not be sufficient to provide for attainment of the current 1-hour standard throughout the eastern United States.

- Ozone reductions in a given region are most influenced by emissions reductions in that same region but are also influenced by emissions reductions in upwind regions. (note: "Upwind" may not imply a specific geographic area but can vary from day to day.)

The remainder of this Appendix will highlight some of the results from individual OTAG simulations. These simulations were taken from the 1995 episode completed by NEMAC. The 1995 exceedance simulation was chosen because there were actual exceedances across Pennsylvania during this time frame. OTAG also modeled episodes from 1988, 1991, and 1993. All simulations were completed using the most recent version of the Urban Airshed Model (UAM-V). The Biogenic Emissions Inventory System (BEIS) was used to develop emissions from biota and this model was updated during the OTAG process (BEIS II). Emissions inventories for the early OTAG simulations were slightly different than the emissions inventories in the final OTAG simulations. Emissions inventories evolved during the modeling process due to inclusions of CEM data and various corrections imposed during QA/QC checks.

1995 Results

Model results from the 1995 OTAG episode were reviewed to determine the potential effects of NOx emission reductions on Pennsylvania. The following is a list of simulations that include reductions in NOx emissions (mostly elevated, but some low-level). Simulation results are shown followed by a short summary of the run's implications.

Sensitivity Runs

Run 3a: -60% NOx (Elevated Point Sources)

Run 5g: -80% NOx (Elevated Point Sources)
-60% NOx (All Low-Level Sources)

Round 1

Run 3: Level 3 NO x Controls on Utilities, Level 0 Non-Utilities

Round 2

Strategy Run 5:

Level 3 Util NOx, Level 1 Area, Level 0 MV

Strategy Run 8:

Level 1 Util NOx, Level 1 Non-Util, Level 1 Area, Level 0 MV

Round 3

Strategy Run Ca & Cb:

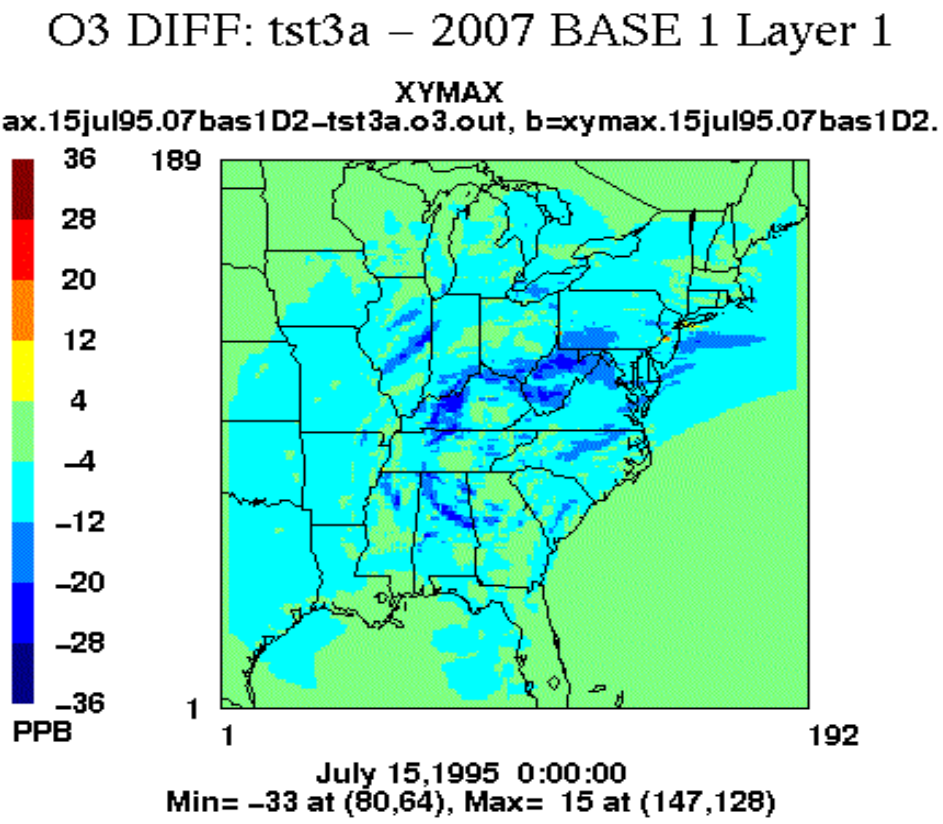
RUN	NAA	III	V	I	II	IV	CG
Ca	2b	2b	2b	2b	1	1	0
Cb	2b	2b	2b	2b	0	0	0

Discussion

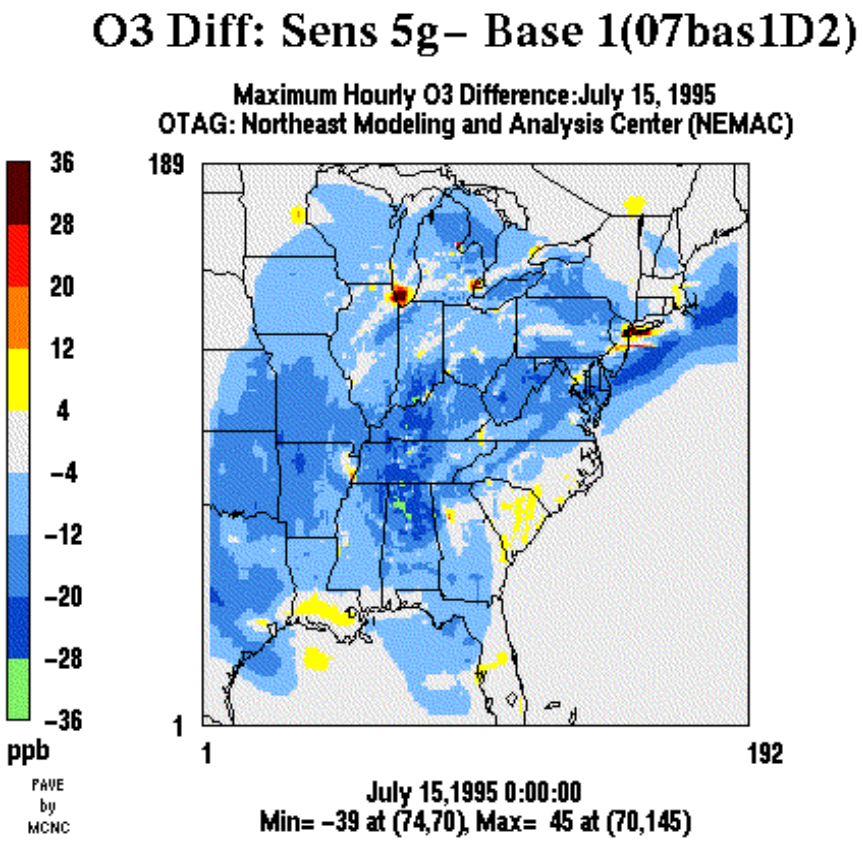
Sensitivity Runs

Run 3a:

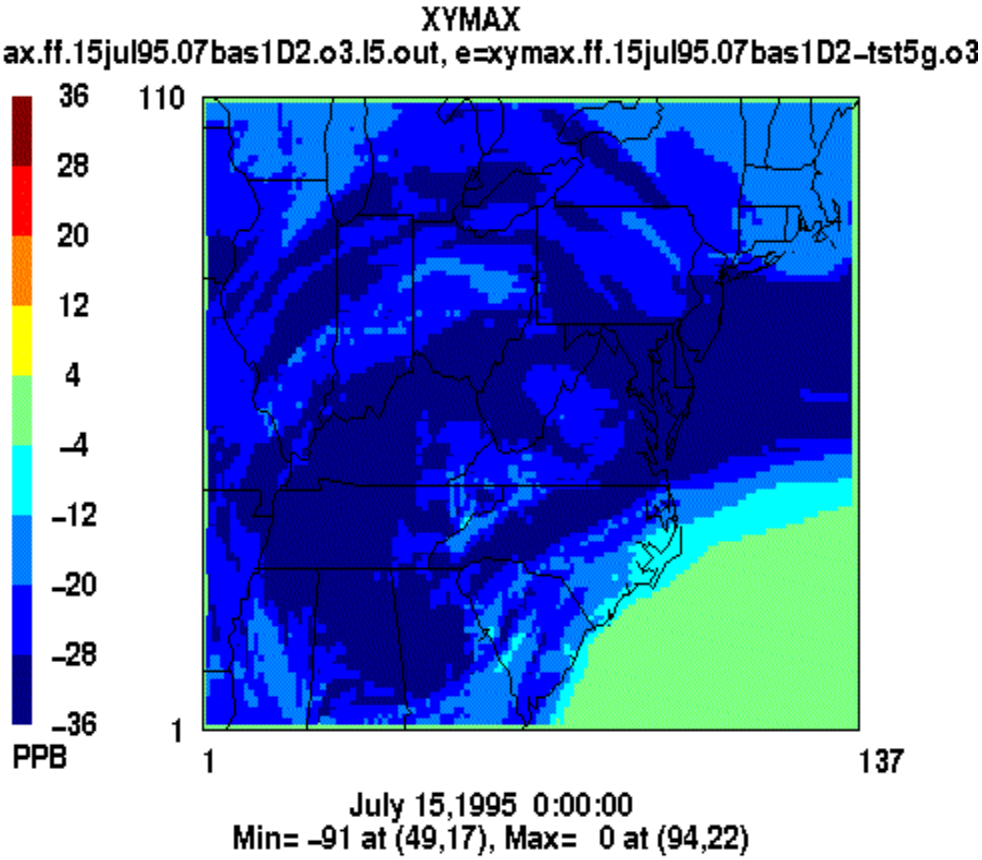
Run 3a was completed as part of OTAG's initial sensitivity simulations. The simulation used an early emissions inventory referred to as base 1a. The plot shown below is a difference plot between the 2007 base-case emissions inventory run (simulates conditions for 2007) and a run with a domain wide 60% cut in elevated point source emissions. Areas of decreased ozone concentrations represent an improvement over the base-case simulation. Results indicate reductions in modeled ozone concentrations ranging from 12-20 ppb in Southwest Pennsylvania, to 4-12 ppb in Northeast Pennsylvania. Results from this simulation demonstrate that Pennsylvania would significantly benefit from domain-wide reductions in elevated NOx emissions.



Run 5g:
Run 5g was also part of OTAG's initial sensitivity runs. Run 5g reduced elevated NOx emissions by 80%, and reduced low-level NOx Emissions by 60%. This simulation, like run 3a, also used emissions inventory 1a. Two plots are shown here. The first plot is a difference plot between the 2007 base-case and run 5g's surface ozone concentrations. The second plot is a difference plot between the 2007 base-case and run 5g aloft ozone concentrations. Aloft concentrations are important because ozone transport occurs at these levels. The surface plot shows modeled ozone reductions on the order of 12-20 ppb in portions of Southwest and Northeast Pennsylvania, with the majority of Pennsylvania having reductions on the order of 4-12 ppb. Modeled aloft concentrations decreased even more than the surface concentrations, on the order of 20-36 ppb over almost all of Pennsylvania. These results demonstrate that domain-wide NOx emissions reductions on the order of 80% for elevated sources and 60% for low-level sources will significantly reduce surface and aloft ozone concentrations over Pennsylvania.



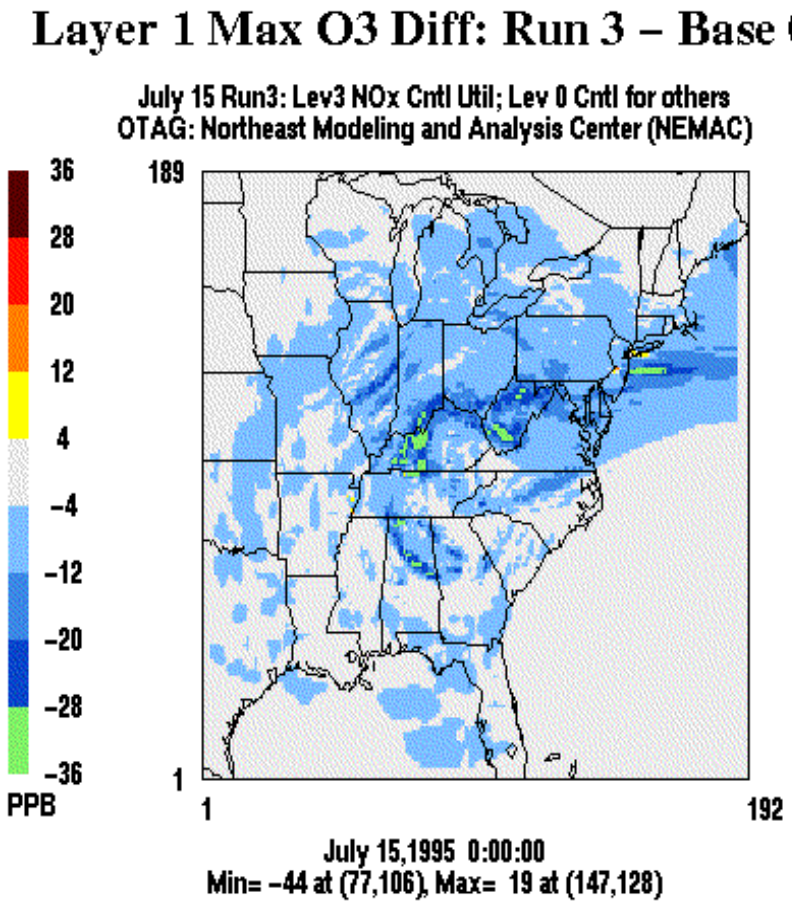
O3 DIFF: tst5g – 2007 BASE 1 Layer 5



Round 1

Run 3:

Run 3 was part of OTAG's round 1 strategy controls. Emission controls were applied domain wide. Run 3 had level 3 controls, the most stringent control level, on utility NOx emissions. The plot shown below is a difference plot between run 3 and the 2007 base-case. Modeled ozone reductions across Pennsylvania are on the order of 4-12 ppb. Larger reductions, on the order of 12-20 ppb, are limited to Western and Central Pennsylvania.

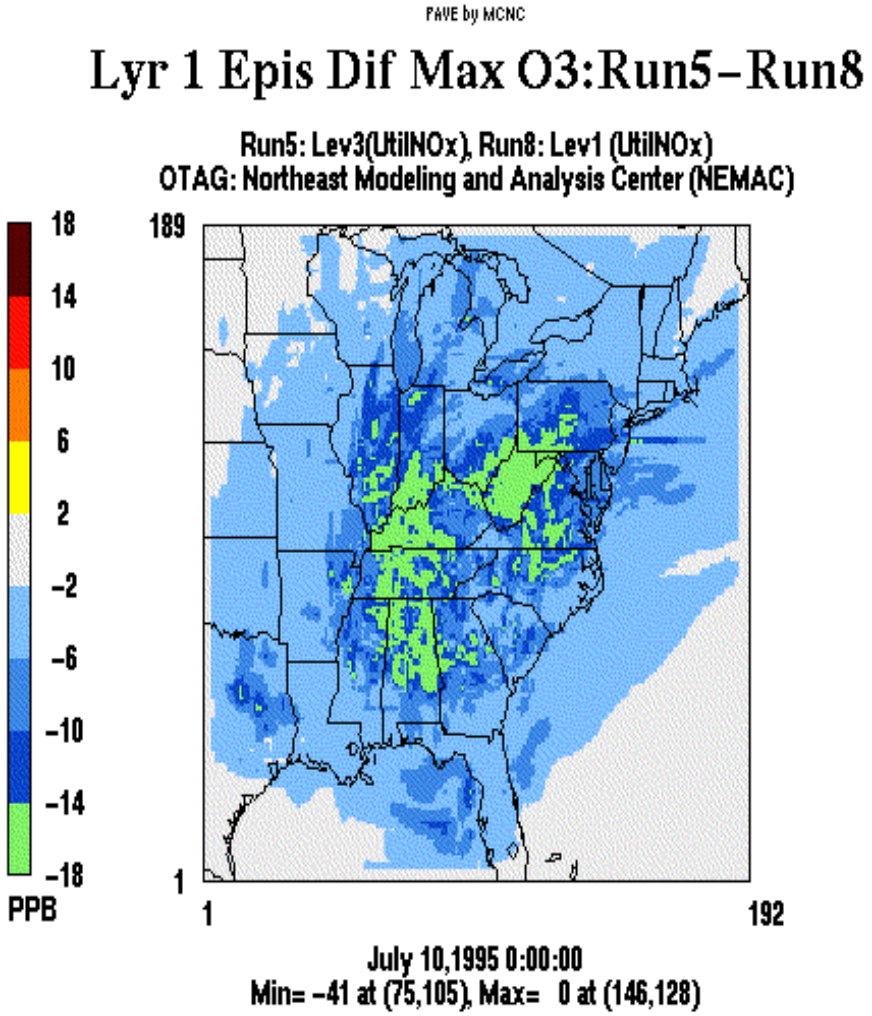


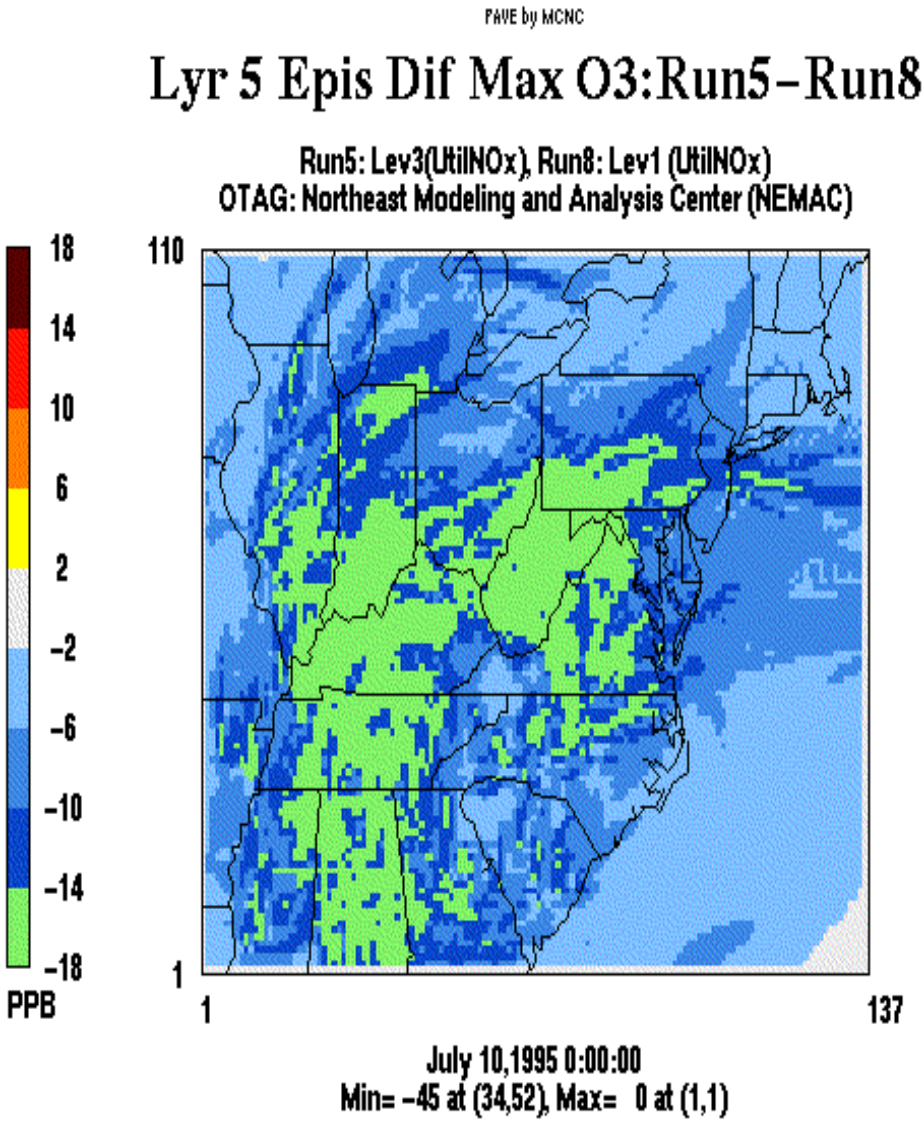
Round 2

Run 5 & Run 8:

Both run 5 and run 8 were part of OTAG's round 2 strategy runs. Run 5 had stringent level 3 controls on all utility NOx emissions within the OTAG domain. Run 8 had level 1 controls on all utility NOx sources within the OTAG domain. Level 1 controls are more stringent than those imposed by the Clean Air Act but less stringent than the level 3 controls applied to run 5. Difference plots between

run 5 and run 8 for layer 1 and layer 5 are shown below. These plots illustrate the benefits of more stringent NOx controls across the entire OTAG domain. Layer 1 shows modeled benefits of 14 ppb or more across Southwest Pennsylvania, with most of Pennsylvania showing modeled reductions of over 6 ppb. Layer 5 (transport layer) modeled ozone concentrations show that enhanced NOx controls across the entire OTAG domain generate even larger ozone reductions.

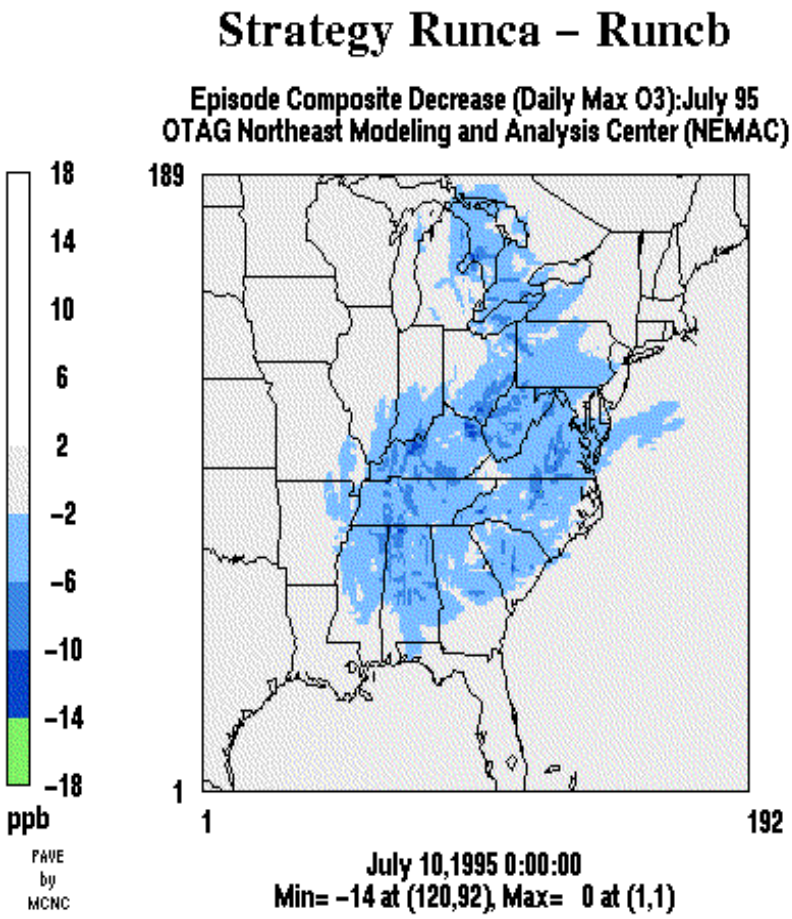



PAVE by MCNC
Lyr 5 Epis Dif Max O3:Run5−Run8
Run5: Lev3(UtilNOx), Run8: Lev1 (UtilNOx)
OTAG: Northeast Modeling and Analysis Center (NEMAC)
18
14
10
6
2
−2
−6
−10
−14
−18
PPB
110
1
1
137
July 10,1995 0:00:00
Min= −45 at (34,52), Max= 0 at (1,1)

Round 3

Run Ca & Cb:

Runs Ca and Cb were supplemental runs in OTAG's round 3 strategy runs. Geographical controls were simulated in this round of modeling. Runs Ca and Cb were the only runs where OTR controls were applied to Western Pennsylvania. Run Ca NOx controls were slightly more stringent for the Ohio River Valley than the controls in run Cb. NOx emission reductions in this round of modeling were less than NOx reductions in the sensitivity rounds. Difference plots showed modeled ozone concentrations dropped 2-6 ppb due to these modest NOx emission reductions.

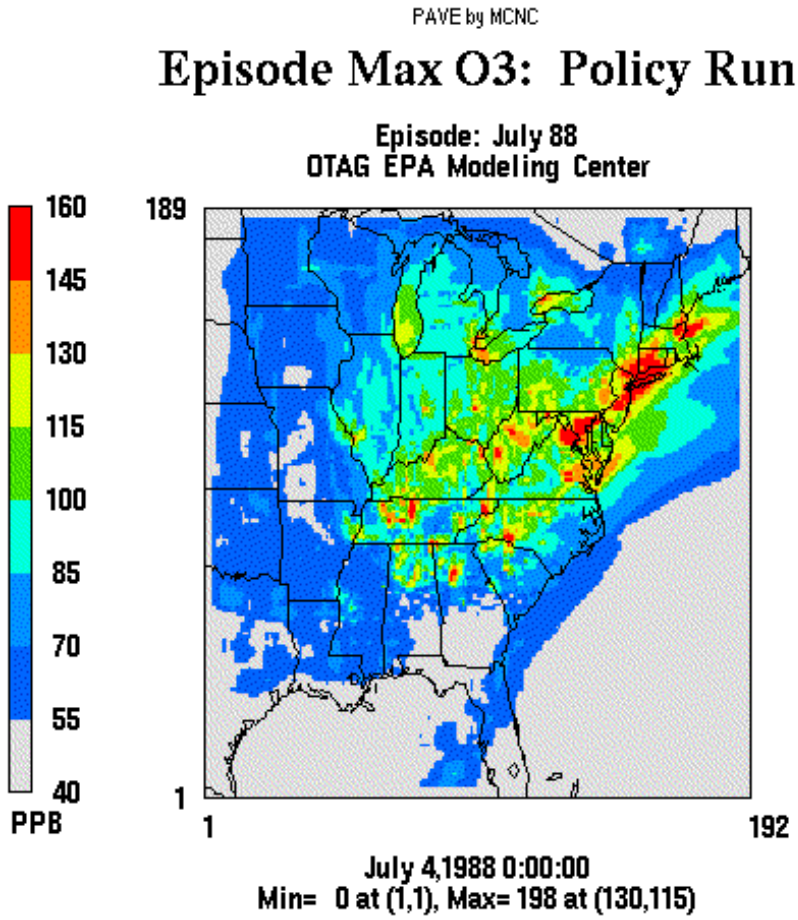


Other Model Results

This section summarizes other modeling efforts whose results support regional NOx emission controls to reduce ozone concentrations in Pennsylvania and the Northeast.

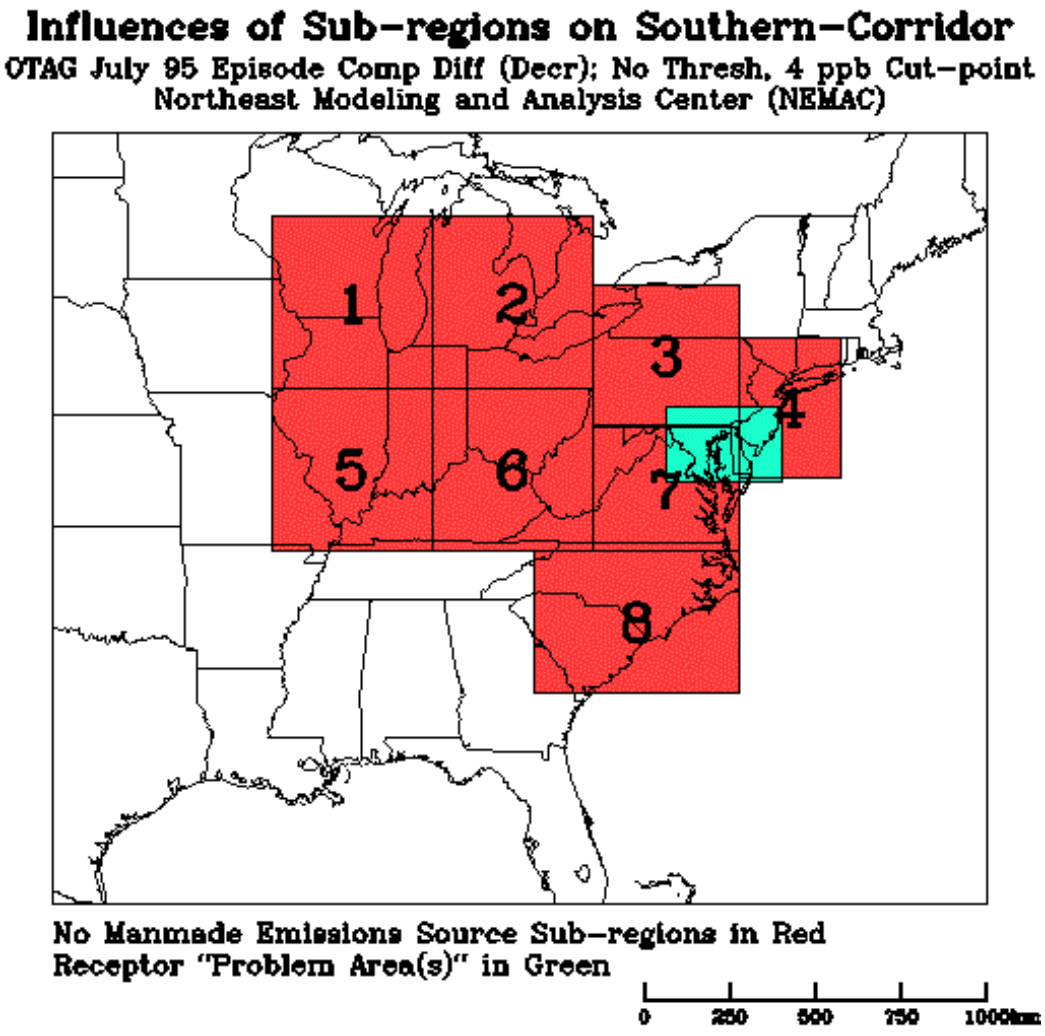
EPA's Policy Run

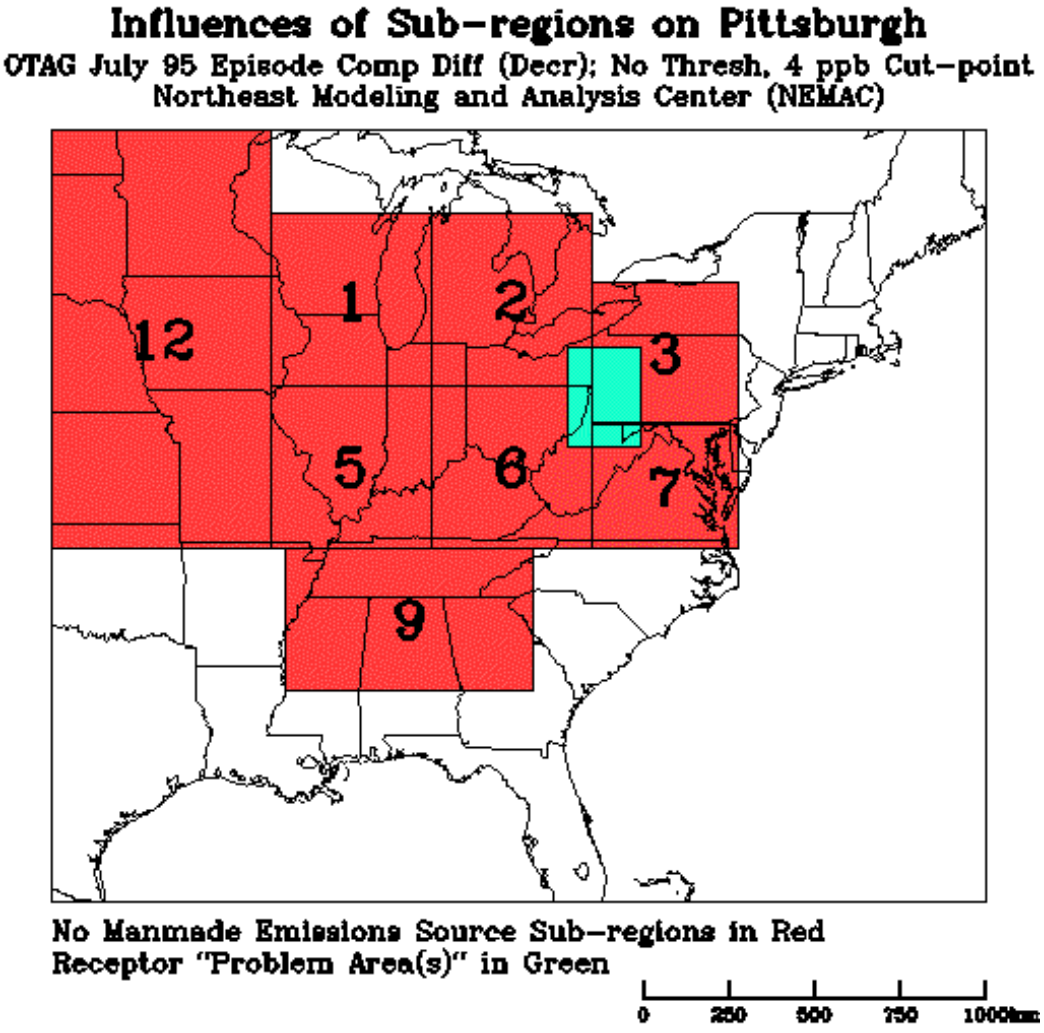
EPA modeled OTAG's 1988 episode. Emission controls for the Policy Run included Clean Air Act emission reductions in all current nonattainment areas plus additional emission reductions within the OTR. Results from this simulation, shown below, demonstrate that even with the Clean Air Act emission controls and the additional OTR emission controls, ozone concentrations in Pennsylvania, as well as the Northeast, remain above the current one-hour standard. This result demonstrates additional emission controls are needed to attain the ozone standard in Pennsylvania and the Northeast. Results from the OTAG modeling group show regional NOx controls would be the most effective strategy to reduce ozone concentrations.



Results from NEMAC's Subregional Sensitivity Runs

NEMAC conducted several runs in which man-made emissions were set to zero within specified subregions of the OTAG domain. The effects of each subregion's emissions on individual urban areas was then assessed. The results for Pittsburgh and Philadelphia (nonattainment areas in Pennsylvania) are shown below. The model results showed a large area of influence for each of these urban areas. Combining both cities' areas of influence shows that a large portion of the OTAG domain is within Pennsylvania's area of influence. The extensive area of influence determined from this modeling exercise demonstrates regional controls are necessary for Pennsylvania to achieve and maintain the ozone standard.





Summary

OTAG has recently completed one of the most extensive ozone modeling projects to date. Ozone was modeled for a 37 state domain using UAM-V. UAM-V is the most current version of the Urban Airshed Model. Among OTAG's modeling conclusions are:

- NOx emissions reductions are more effective than VOC emissions reductions in lowering ozone concentrations on a regional scale; NOx reductions decrease ozone domain wide, while VOC reductions decrease ozone only in urban areas.
- Elevated and low-level NOx emissions reductions are both effective in lowering ozone concentrations on a regional scale.
- More NOx emissions reduction results in more ozone benefit.
- Regional NOx emissions reductions due to Clean Air Act mandatory controls, as well as possible OTAG controls, will reduce ozone and ozone precursors on a regional scale but may not be sufficient to provide for attainment of the current 1-hour standard throughout the eastern United States.

A survey of OTAG modeling for the 1995 episode indicated that control strategies that included domain-wide NOx reductions consistently reduced ozone concentrations over Pennsylvania. Modeled ozone concentrations were reduced up to 20 ppb at the surface. Reductions in modeled aloft ozone concentrations were about the same as reductions at the surface, but generally covered a larger area. Aloft concentrations are important because regional ozone transport occurs in these layers. Aloft modeled ozone reductions are, therefore, interpreted as a reduction in ozone transport into and out of Pennsylvania.

Other modeling studies also support the need for regional NOx controls. The Policy Run completed by the EPA showed that even with Clean Air Act emission controls in nonattainment areas and additional emission controls within the OTR, there are still wide-spread exceedances of the current one-hour ozone standard in Pennsylvania and the Northeast. This result demonstrates additional controls are needed to reach attainment. Regional NOx controls would be an effective strategy to reduce ozone concentrations in Pennsylvania and the Northeast.

Area of influence determinations completed by NEMAC indicated a wide region of influence for Pennsylvania. The areas of influence for Pittsburgh and Philadelphia included most of the OTAG domain.